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A COMPLETE OVAL AUSTRALITE

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Abstract

A rare, button-like, exceptionally well-preserved australite with oval outline and a complete, perfectly developed circumferential flange, reveals excellent structures that lend strong support to the Aerodynamical Control Theory of the secondary shaping and sculpturing of primary forms of australites.

The anterior surface of the specimen has a clockwise spiral flow ridge, pronounced radial flow lines, and a dimple-like depression that represents a remnant of an internal cavity exposed and modified by front surface ablation. These phenomena testify to sculpture of the leading surface of a primary oblate spheroid of extraterrestrial glass during aerodynamically orientated flight at high speeds through the earth's atmosphere.

The posterior surface of the lens-like body portion of the australite reveals primary flow swirls and occasional bubble pits whereas the posterior surface of the secondarily developed circumferential flange is generally smooth apart from a few narrow flow lines with a concentric trend.

The excellent state of preservation of the specimen indicates its short geological history.

Introduction

The perfect, flanged oval australite described herein from Port Campbell is one of the very few known excellently preserved complete oval-shaped australites in which flange and core are entire and firmly attached together. Numerous oval-shaped forms are known from which the flanges have been partially or entirely removed by erosion.

The term 'perfect' is here used to imply that the australite is an especially well-developed form, the primary shape having been modified by secondary processes involving atmospherical flight sculpturing that led to the production of a secondary shape that has been preserved in its entirety without being affected by tertiary processes of subaerial erosion. Compared with perfectly preserved australite buttons which are circular in plan aspect, this oval form has one diameter slightly longer than the other. In the Port Campbell collection containing this specimen, the ratio of perfectly preserved, well-developed flanged button-shaped circular forms to perfectly preserved, well-developed flanged oval form, is 27:1, and it is the only member of the oval shape group with the flange preserved entire.

Occurrence

The perfect oval was collected on 27 December 1936 from the cliff edge above Rutledge's Creek Beach near Bumpy Rock, 3½ m. SE. of Port Campbell township on the S. coast of Victoria. It occurred approximately 10 ft from the edge of 80 ft vertical marine cliffs cut in Miocene sediments (Port Campbell Limestone), and rested on aphanitic limestone amid the weathering products of the stripped zone (cf. Baker 1958a) that forms a bevelled edge at the top of the cliffs. The anterior surface of the specimen faced upwards, this being the normal position of rest of australites after landing on the earth's surface from an extraterrestrial source, but there is no evidence clearly revealed at the site of discovery that would indicate the precise level of the earth's surface upon which the specimen landed, nor of any effects produced on impact with the ground. Associated materials at the site are normal terrestrial products.

The specimen was washed out of the top 6 in. of surface soil of Recent age some time during 1936, for the same spot had been searched thoroughly in January of the same year. The Recent soil here rests upon post-Miocene sandy clay that forms a veneer on the limestone along the landward fringes of the stripped zone, and which, like the Recent soil, has largely been removed by subaerial agencies from the edges of the cliff tops. The perfect oval had evidently not been moved more than a foot or so laterally, and less vertically, since exposure, and its well-preserved condition bears testimony to the virtual absence of the effects of both abrasive agents and etching solutions. The area is in a temperate region subject to an average annual rainfall of 30 in.

Shape, Weight, Specific Gravity and Radii of Curvature

The oval shape of the specimen in plan aspect arises from one diameter being 2 mm. longer than in a direction at right angles. This contrasts with the perfect, flanged button-shaped australites which typically are more or less circular in plan outline. Although this difference in diameter is relatively small and represents only 8·5% of the overall diameter measurements, it is sufficient to reveal the oval outline to the unaided eye. The longer diameter is 24 mm., the shorter diameter 22 mm., and the depth, which is the thickness measured along the polar axis, is 8·5 mm.

The specimen weighs 5·115 gm., and its specific gravity is 2·376 (T. water = 22°C.); this is significantly lower than the average specific gravity (2·400) for australites from SE. Australia.

Whereas the radius of curvature of the posterior surface (R_B) as determined in the polar regions, is 13·93 mm. for the direction containing the shorter diameter, the value for R_B in the direction at right angles, containing the longer diameter, is 17·23 mm., so that the arc of curvature is slightly flatter across the longer axis of the specimen (cf. Baker 1955, p. 201). The radius of curvature of the anterior surface (R_F) is 13·20 mm. along the shorter diameter, and 16·00 mm. along the longer diameter, and the arc of curvature is thus also flatter across the longer axis of the lens-like core portion of the specimen. The intercept of the radical line (cf. Baker 1955, p. 168) on the polar axis in this specimen is such that the front and rear poles are each spaced approximately 4·5 mm. from the centre of the lens-like core of the flanged oval, and since R_B and R_F values are not very different, the core is fairly regularly biconvex and lenticular in side aspect (cf. core portion, Fig. 1B). The lens-like character is evident for directions through the polar axial plane taken across both the longer and shorter diameters, although the radical line is slightly longer along the longer axis of the specimen. Circles constructed around the two arcs of curvature revealed in silhouette traces taken at right angles, are not truly in accord with the surface curvatures of the specimen; this is due to front polar and rear polar regions being slightly flatter, while the curvature approaching the equatorial edges of the two surfaces is slightly steeper. This means that the arcs of curvature of neither surface are truly circular, but the departures are of small amount in not exceeding 1 mm. at any one point.

Circumferential Flange

The circumferential flange (Fig. 1A) is a secondary structure as regular in character and developed in precisely the same way as the perfectly formed circumferential flanges on the button-shaped australites which are more nearly circular in plan aspect. The same applies to other types of elongated australites in which the two diameter measurements, width and length, show greater differences in value; i.e. forms such as narrower ovals, boat-shaped forms and dumbbell-shaped forms.

When observed against a strong light, the relatively thin flange (thickness 1 to 2 mm.) is translucent throughout and reveals some internal flow lines but no internal bubbles can be detected in either flange or the thinner edges of the lens-like core The relatively low specific gravity (2·376) of the specimen is therefore not likely to be due so much to internal bubbles in the more opaque parts of the lens-like core, as to composition variations. Since the SiO_2 tenor of tektite glass increases sympathetically with decrease in specific gravity, the lower specific gravity value compared with the average for australites (2·400) is more likely a reflection of a higher silica content.

The flange was formed by accumulation of melt glass forced from the stagnation point of the front polar regions to the equatorial periphery of the lens-like core as a result of secondary processes of front surface heating. It formed relatively late in the phase of melting and ablation which was brought about by the effects of aerodynamical phenomena operating for a limited period of time on the forwardly directed surface of an oblate spheroid. This was the primary form that traversed the earth's atmosphere at ultrasupersonic velocities and which maintained an aerodynamically stable position of flight while these high speeds prevailed (cf. Baker 1944, 1955, 1956, 1958b, 1959).

Posterior Surface

The posterior surface (Fig. 1A) is that surface which remained at the back of the fast-moving australite during its ultrasupersonic flight through the earth's atmosphere. It reveals (Pl. IX, A) primary flow-lined patches of smoother glass, known as 'flow swirls' (Baker 1959, p. 40), and a few small bubble pits on the lens-like core which impart a vesicular appearance to part of the surface. The lens-like core is girdled by a relatively smooth surfaced circumferential flange of constant width (3 mm.) and free of bubble pits. A few fine flow lines on the posterior surface of the flange principally trend parallel with its inner and outer edges, and hence are essentially concentric (Fig. 1A).

The primary flow swirls have been preserved because of insufficient aerodynamical heating to cause secondary melting at the rear of the form at any stage throughout ultrasupersonic flight. Their production as original sculptural elements when the oblate spheroid initially consolidated in an extraterrestrial environment, is substantiated by the fact that similarly flow swirled areas on posterior surfaces of fragmented specimens broken normal to the surface, are observed to be surface expressions ('outcrops') of an internal flow pattern that penetrates to the central regions of the lens-like core. Had they been due to localized secondary melting at the onset of, or during, rapid transit through the earth's atmosphere, the flow lines constituting the swirls would have been entirely superficial in precisely the same way as those in the secondary melting phenomena revealed in the 'seat' regions close to the bases of the flanges (cf. Baker 1959, p. 40) and on the

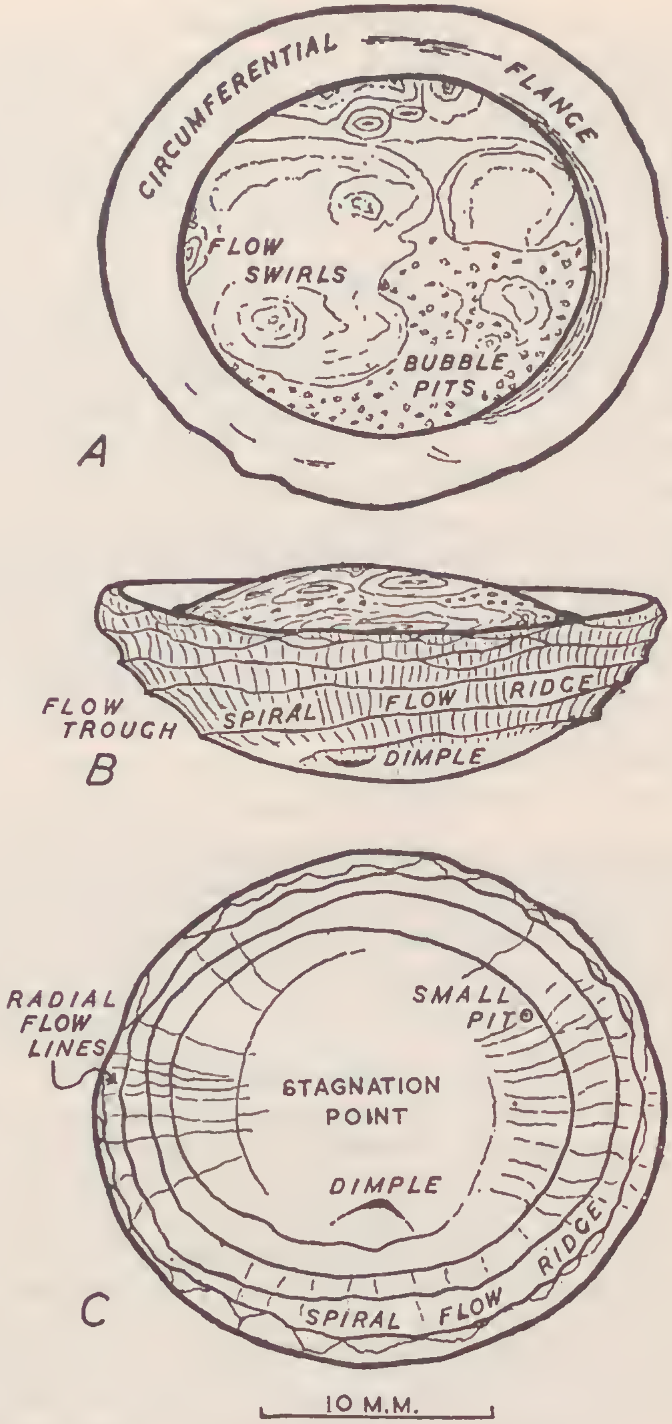

Fig. 1—Sketch diagram of complete oval australite from Port Campbell, Vic.

A—posterior surface showing body core with flow swirls and bubble pits, and circumferential flange with occasional concentric flow lines.

B—side aspect showing flow troughs between spiral flow ridge with radial flow lines. The posterior surface of the flange dips inwards at 14°.

C—anterior surface showing dimple, small pit, radial flow lines and clockwise spiral flow ridge in relationship to the stagnation point. The flow ridge becomes rippled approaching the periphery of the anterior surface of the flange.

anterior surfaces in these regions. The flow swirled patches of glass are of a streaky nature and almost free of bubble pits, and are set in a surround of tektite glass that was the site of more abundant gas bubble escape which gave rise to surface vesicularity (cf. Pl. IX, A).

Anterior Surface

The anterior surface (Fig. 1C) was the forwardly directed surface of the oblate spheroid during the ultrasupersonic and later supersonic phases of atmospheric flight. As a consequence it has been secondarily modified all over by the effects of ablation, progressive thin film superficial melting, and some fusion stripping. This was achieved during phases of increased pressures and temperatures generated in the shock wave phenomena created in a resisting atmospheric medium.

It reveals a well-developed, perfectly preserved clockwise spiral flow ridge (cf. Baker 1959, p. 38) which has its origin nearly midway (see Fig. 1C) between the stagnation point (point of origin of boundary layer flow in the air in contact with the front polar regions) and the equatorial edge of the specimen (Pl. IX, B). The ridge is essentially in the form of a descending helical spiral with its apex in the vicinity of the front pole; it becomes rippled approaching its base at the outer edge of the circumferential flange. Near the periphery of the anterior surface, complexities arise in the rippled flow ridge due to interference and a dimpled effect results (see edge of Pl. IX, B). The dimples are situated in a region where turbulent airflow supervened, and were evidently produced as a consequence of the dominance of frictional over pressure forces in the boundary layer flow. An effect of these dimpled areas becoming more pronounced is to produce minor irregularities in the configuration of the flange as seen in plan and side aspects of the anterior surface of the specimen (e.g. top left-hand portion of Pl. IX, B). The spiral ridge represents the last melt glass to be forced from the stagnation point regions and frozen in place; this occurred at a stage when the processes of aerodynamical ablation and melting had moderated at decreased speeds of atmospheric transit.

The depressed area (see 'dimple' in Fig. 1C) near the stagnation point on the anterior surface (Pl. IX, B—bottom centre) is a remnant of an internal bubble that was exposed by the progressive ablation and thin film melting of tektite glass. Its exposure occurred at a stage when it could have interrupted the regular development of the normally produced concentric type of flow ridge, and its presence no doubt controlled the ultimate clockwise spiral nature of the flow ridge (cf. Baker 1956, pp. 42-43). This conclusion is based on the evidence provided by other perfectly preserved specimens of flanged australites. In these, it is observed that the best developed concentric flow ridges are produced when ablation levels are completely free of exposed internal bubbles. Spiral ridges, whether clockwise or counter-clockwise in sense, are usually found on specimens at which the ablation level had penetrated to a depth below the original front surface where internal bubbles were encountered around the stagnation point area. On some specimens, pitting by aerodynamical etching out of rather more readily removed tektite glass, rather than the presence of internal bubbles, may have controlled the development of the spiral ridges. The spiral ridges trend around the outer edges of such exposed internal bubbles, i.e. around the sides remote from the stagnation point; some have remained even though the last traces of the depression have gone, but some may have ultimately passed back to the concentric type of flow ridges provided no further irregularities appeared on the progressively ablating and melting surface.

An important feature of the dimple referred to, is its noticeably shallower side nearest the equatorial periphery of the specimen, i.e. on the side remote from the stagnation point. This condition is to be expected, because once exposed, the original internal bubble cavity would temporarily act as an energy trap, and most impinging particles of both the air and the melt glass moving outwards from the stagnation point, would be reflected from its side walls. Inasmuch as the boundary layer flow trends radially outwards from the stagnation point, that portion of the rim of the exposed cavity situated furthest from the stagnation point would receive the more direct impacts, and hence would be subjected to more intensive melting and ablation than the lip of the cavity nearest the stagnation point.

The size of the internal cavities exposed at various levels of ablation can vary from a fraction of a millimetre to 25 mm. or more across. Exposure of the smallest cavities has but minor effects, while exposure of the larger cavities results in major complexities. The phenomena discussed herein arise more commonly when the exposed cavities are 2 to 5 mm. in diameter. The effects of their exposure on the aerodynamical stability of the specimen are at present difficult to assess, but it is to be expected that exposure of the largest internal cavities will have the more profound effects, while those of smaller size like the one under discussion may only cause slight wobbling or tipping as a phenomenon associated with drag and buffeting during high speed flight. Wobbling, or tipping slightly to one side, could provide the bias necessary to cause glass moving away from the stagnation point and away from the lip of the exposed cavity to spiral away towards the equator of the specimen. The direction or amount of tipping relative to the position of the exposed cavity at the ablation level reached on the front surface at that particular instant, might well determine whether the outward spiralling motion develops in a clockwise or in a counter-clockwise sense.

Exposure of the smallest internal cavities, i.e. those under 1 or 2 mm. in diameter, is likely to create less important effects, but they would act as centres of small amounts of aerodynamic etching. The minute example shown on the stagnation point side of the flow ridge in Pl. IX, B (centre top right) is only 0·75 mm. across, but it has remained circular in outline and its walls still reveal a high degree of 'hot polish' compared with the dimple (Pl. IX, B—bottom centre) of larger size that has been considerably modified by aerodynamical heating. The opening of the small cavity is still slightly less than its maximum diameter; it is thus to be regarded as a minute pit that was exposed by the final phases of thin film anterior surface melting. Its rim is rather more sharply defined on the side nearest to the stagnation point, and slightly rounded off on the side furthest away.

Narrow flow lines and slightly broader, shallow flow channels trend radially outwards from the vicinity of the stagnation point on the anterior surface (Pl. IX, B), and can be traced uninterruptedly across the clockwise spiral flow ridge (Fig. 1B and 1C). These are secondary flow structures of entirely superficial character. They and the minute bubble pits are sites for initial etching out of the tektite glass by a tertiary process of solution etching that commences after the form has landed on the earth's surface. This process has begun to make itself evident on parts of the anterior surface of the aerodynamically modified oblate spheroid, but has not advanced to any marked degree. The fact that these flow streaks ('schlieren') etch out rather more readily, is a pointer to their chemical composition being a little different from that of the tektite glass between the channeled portions.

Although several of these radial flow lines cut right through the flow ridges, slightly interrupting the continuity of their crests, this is evidently not a true effect of the sculpturing by the aerodynamical phenomena. Close inspection of other flow lines under a binocular microscope reveals their occurrence in bundles that appear to terminate abruptly near the stagnation point side of each flow ridge and reappear on the side remote from the stagnation point, after which they continue their trend across the surfaces of the flow troughs (Fig. 1B) that intervene between the crests of the ridges. These features can be just detected on the left-hand side of the photograph of the specimen (Pl. IX, B).

When bundles of flow lines become directions of etching by soil solutions and other subterranean waters, differential attack frequently results in undermining on a micro-scale of the glass occurring along the trends of the flow lines. The sub-surface spaces so formed sometimes become occupied by thin films of very fine-grained terrestrial mineral matter. This is often a fine ferruginous clay substance of dark brown, red or yellow colour resembling ochre, but sometimes it is leached and then appears buff-coloured or may be whiter, more especially when minute particles of detrital quartz are also carried in along the small 'solution tunnels'. Diurnal temperature changes resulting in differential expansion between the introduced mineral matter and the remnant portions of the tektite glass, lead to minute fracturing away and further slight lifting of thin films of the glass, so that by progressive solution etching followed by thin sliver fracturing and further solution etching along these pre-determined directions, overdeepening can occur, accompanied by lesser amounts of lateral widening. In this manner, narrow, relatively deeply penetrating so-called 'cracks' arise, and these sometimes reach from the equatorial edges of otherwise perfectly preserved australites right through to the central regions, and they can extend also from pole to pole as well as from edge to centre. They have been regarded in some quarters as contraction cracks, but the evidence points to an origin by solution etching during burial in soils and sliver fracturing as an outcome of diurnal temperature changes affecting already partially etched out channelways. This process can be traced in a sequence of events starting from initial undermining of the flow ridge glass and passing through the stage of the appearance of mineral matter under the flow ridge crests, through the stage when parts of the glass on the crests of the flow ridge are etched out to form a minute notch, and on to progressively deeper channeling with the ultimate production of what at first sight might be taken as deep contraction cracks. Many fragments of australites have apparently resulted from the operation of these processes, and the parallel surfaces, which are by no means always straight, of the overdeepened 'gutters', invariably reveal the complex internal flow line pattern of both circumferential flange and of lens-like core. Another important effect of this differential etching phenomenon, brought about by the process concentrating all around the 'seat' region (cf. Baker 1959, p. 40) of the flanged australites, is that planes of contact between flange and lens-like core become considerably weakened, so that the flange eventually becomes detached either as a complete entity (cf. Baker 1946, Pl. XIII; 1956, Pl. I) or in fragments.

It becomes evident that in the newly formed condition, the flow ridges consist of rather less streaky glass 'frozen in' and perched on top of radially flow lined glass which is some 0·25 mm. and less below the levels of the crests of the ridges. The radially flow lined glass is thus most prominently displayed on the surfaces of the troughs between the ridges, and the width ranges from 4 mm. between the crests of ridges nearest the stagnation point to under 1 mm. between the ridges nearest the periphery of the flange (Fig. 1C). In thin sections through these structures in australites (cf. Baker 1958, p. 377) subsurface flow line patterns in the ridges are parallel with the trends of the superficial flow lines generally, and under higher magnifications the flow lined regions of the intervening troughs are seen to be sharply truncated (cf. Baker 1944, Pl. III, fig. 1). Any anticlinal patterns that might be expected if the glass had flowed into and up and over the flow ridges, are thus apparent only when viewed under lower magnifications, and do not represent the true state of affairs.

Conclusions

The secondarily developed configuration of the complete, flanged oval australite described, the detailed structures on the posterior and anterior surfaces of its circumferential flange, and the sculpture pattern of the whole of the anterior surface of the australite, are all consonant with formation from a primary oblate spheroid of tektite glass that entered the earth's atmosphere at ultrasupersonic velocity and became modified by ablation, melting and some fusion stripping of its forwardly directed surface during aerodynamically orientated flight. The oblate spheroid was evidently of the biaxial ellipsoidal type rather than triaxial.

The well-preserved character of the perfectly developed flanged oval form is no doubt due to its relatively young age in terms of the time of arrival upon the earth's surface, and to its occurrence in a milieu where processes of abrasion, insolation and solution etching have been at a minimum during the 5,000 years or so that it has lain in a terrestrial environment.

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Explanation of Plate

Plate IX

Posterior surface (A) and anterior surface (B) of complete oval australite from Port Campbell, Vic. (×4) (Photo by A. A. Baker)